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LEVEL II

DAIS MODELS SIMULATION SYSTEM (DMSS)

Audrey A. C. Brewer
Systems Consultants, Incorporated
1010 Woodman Drive
Dayton, Ohio 45432

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Final Report for Period
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STEPHEN L. BENNING, PROJECT ENGINEER
System Avionics Division

L. DANIEL SNYDER, Chief
Mission Software & System Integration Gp

FOR THE COMMANDER

RAYMOND E. SIFERD, Col, USAF
Chief, System Avionics Division
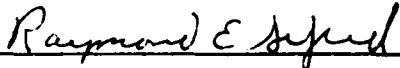Avionics Laboratory

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The DMSS software support effort enhanced the capabilities and value of DMSS by accomplishing the following four objectives: (1) Addition of VATS/Pave Tack and Maverick Missile models; (2) Enhancing the existing software; (3) Creating meaningful, up-to-date documentation; and (4) Providing comprehensive training. The new models were developed using top-down structuring techniques and were implemented in RATFOR (a structured FORTRAN preprocessor). The existing models were restructured using top-down structuring techniques, RATFOR, and meaningful comments. The documentation was updated to adhere to MIL-STD-483 and 490.

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PREFACE

This Final Technical Report was prepared by the Dayton, Ohio Operating Center of Systems Consultants, Incorporated (SCI). The DAIS Models Simulation System (DMSS) software support effort enhanced the capabilities and value of the DMSS through accomplishing the following four objectives.

(1) Addition of new models required for the demonstration
    missions;

(2) Enhancing the existing software;

(3) Creating meaningful documentation; and

(4) Providing comprehensive training.

The effort was initiated with contract go-ahead on 14 June 1979 and was completed on 14 November 1980. Mr. S. L. Benning was the Laboratory Contract Monitor for the Avionics Laboratory within Air Force Wright Aeronatics Laboratory (AFWAL/AAAS). Under his direction and with the operation of DAIS staff and other Air Force technical and management personnel, the objectives of the DMSS Software Support effort were successfully accomplished.

SCI's Dayton Operating Center under the management of Mr. Walter D. James was responsible for project execution. The Project Manager was Ms. Audrey Brewer. She was ably assisted by Mr. John Murray, Ms. Bette Johnson, Ms. Linda Scheer, and Ms. Maureen Orso. Mr. Dave Brazil provided additional support which contributed to the overall success of the effort.

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SECTION I

INTRODUCTION

DMSS DESCRIPTION

The DMSS simulates the avionics sensors, weapon subsystems, and aircraft/environment in the performance of a Close Air Support (CAS) mission during demonstrations of the Digital Avionics Information System (DAIS). An overview of the DMSS is presented in Figure 1.

DMSS is presently hosted on a DECsystem-10 as part of the Avionics System Analysis and Integration Laboratory (AVSAIL) facility required to support a laboratory demonstration of DAIS. The facility includes a realistic cockpit mock-up with the core elements of DAIS operating as they would in an aircraft. The key items of the support equipment are the mission software processors and their resident software which provide the test control, monitoring, and responses necessary to perform the DAIS demonstration.

The DMSS simulates the aircraft, environment, and various sensors and weapons; as well as co-ordinating the Heads Up Display and out-the-window scene. The main function of the DMSS is to respond to cockpit controls and mission software. Other functions which DMSS can perform are:

(1) Log simulation data for post-run analysis;

(2) Snapshot simulation system variables; and

(3) Reset simlation variables to snapshot values.

The DMSS consists of the following seven functional types of software and their subsets as follows:

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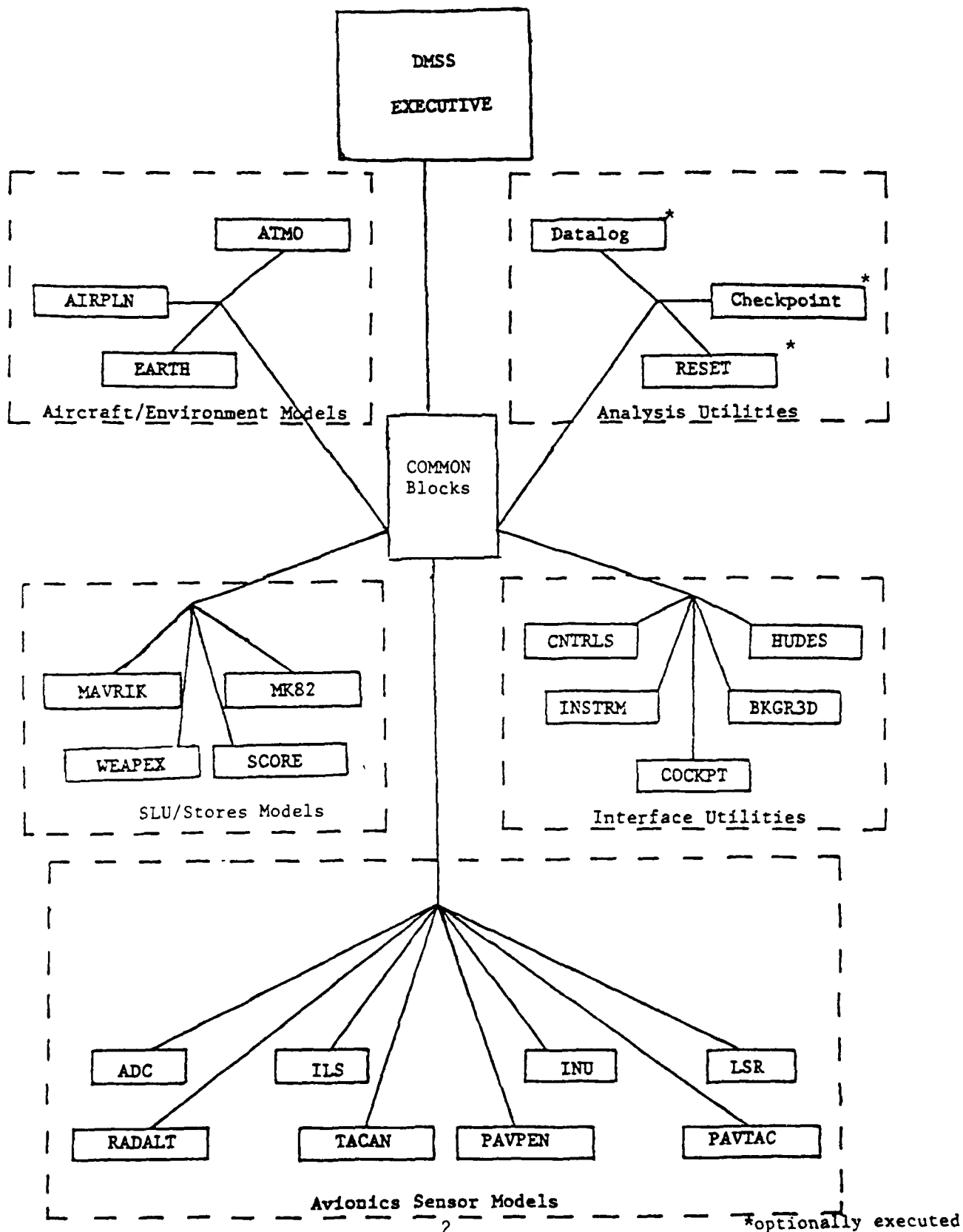
Figure 1
Overview of DMSS Data Flow

*optionally executed

(1) Executive software - responsible for control of the simulation.

(2) Sensor Models - simulate the following aircraft sensors:

- Air Data Computer (ADC);

- Radar Altimeter (RADALT);

- Tactical Air Navigation System (TACAN);

- Inertial Navigation Unit (INU);

- Laser Ranger (LSR);

- Instrument Landing System (ILS);

- VATS/Pave Tack (PAVTAC); and

- Pave Penny (PAVPEN).

(3) SLU/Stores Models - simulate a MK-82 low drag general purpose weapon system (MK82) and the Maverick Missle (MAVRIK), and also scores possible hits on demonstration targets.

(4) Aircraft/Environment Models - provide A-7 airframe dynamics, flight control dynamics, and propulsion information through the following:

- Airplane Model (AIRPLN);

- Earth Model (EARTH); and

- Atmosphere Model (ATMO).

(5) Interface Utilities - provide access to the Crew Station Cockpit controls and displays, and to the Evans and Sutherland Picture System via the following:

- Cockpit Switches (COCKPT);

- Controls (CNTRLS);

- Instruments (INSTRM);

- HUD/Evans and Sutherland Picture System (HUDES); and

● Three-Dimensional Background (BKGR3D).

(6) Data logging - records data during simulation. The data logged can be analyzed using Data Reduction and Analysis Software and/or VIEW after termination of the simulation.

(7) Checkpoint/Reset - provides the capibility to reset the scenario during both real-time and non-real-time system operation.

OBJECTIVES

With the increasing cost of software development, the availability of a system as versatile as the DMSS can reduce costs by being transferred into a general library where several organizations can use it to its fullest potential. With updated documentation, improved source code, and training classes to familiarize users with the capabilities of this powerful simulation system, the longevity of DMSS could be increased. However, prior to this effort DMSS was not properly documented, easily maintainable, or transportable.

SECTION II

BACKGROUND

DMSS EVOLUTION

The DMSS experienced a history of growth which during several different groups implemented and maintained a common software system. In cases such as this, the overall performance of the software was potentially undermined with errors, lack of speed, and excessive core useage. Problems with such "adopted" code were non-uniform design and documentation practices, which subsequently lead to interface and maintenance problems.

The DMSS increased in size and complexity to support the expanding requirements of DAIS concept demonstrations and feasibility analyses. As new missions evolve with increased model requirements, the core size and execution time metrics become critical factors. The continued long term usefulness of the DMSS is enhanced through a combined effort of optimization and thorough documentation. The ultimate value of a software system is determined not only by how well the software works, but by how well it is documented, how easily it is modified, and how readily it is transferred.

The DMSS evolved from several different aircraft simulation efforts. Some of the models were provided by General Dynamics, some were modified Naval Weapons Center models implemented by SCI, while other have been developed by yet other contractor and government personnel. Additionally, the DECsystem-10 operating system contains non-standard executive and utility routines specially designed for the facility. This "conglomeration" of source code was documented during early 1977. At that time some routines were found to be poorly organized and had some obvious errors or extraneous

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code.

OBJECTIVE OF THE EFFORT

The principal objective of the effort was to provide AFWAL with a fully-documented, easily maintained, adaptable, and portable aircraft/sensor/environment simulation system. The attainment of this objective would significantly enhance the value of the DMSS by ensuring continued, long-term use by other laboratory activities and future system program offices. Subsets of this objective include the development of new models, optimization of existing software, training, and complete, accurate documentation of all DMSS code.

SCOPE OF THE EFFORT

The scope of this effort addressed the following general task areas:

- The addition of the new models needed for the demonstration missions (VATS/Pave Tack and the Maverick Missile).

- Enhancing the existing software for increased efficiency, maintainability, and portability.

- Providing the Air Force with current and meaningful documentation.

- Providing comprehensive training.

Through updating of the DMSS software for efficiency and portability and developing current, accurate, and useful users' documentation, DAIS mission demonstrations will be facilitated. Continued, long-term usefulness of the DMSS will also be ensured. The general task areas discussed in this section are presented in more detail in subsequent sections of this report, which is organized as follows:

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- Section III, Technical Approach - describes the method-
  ology used in this effort to accomplish the objective
  outlined in this section.

- Section IV, Deviations/Modifications - details any
  deviations/modifications from original technical effort
  and rationale for the changes.

- Section V, Observations and Recommendations - contains
  observations made during the course of the effort which
  relate to the current and future DMSS. Recommendations
  are also provided relative to future candidate
  modifications and enhancements.

SECTION III

TECHNICAL APPROACH

OVERVIEW

The DMSS Software Support effort had two principal objectives. The
first was to provide AFWAL with a fully documented, maintainable, adaptable,
and portable aircraft/sensor/environment simulation system. The second was
to provide a system of enhanced capabilities and value to ensure that future
DAIS mission demonstrations are facilitated. The objectives of the effort
were met by applying sound and proven system engineering practices. The
approach included:

- Portability and ease of maintenance through well
  structured design, coding, and documentation.

- Up-to-date documentation of the present DMSS, new
  models, and modifications.

- Coordination and liaison with DAIS, System Integration
  and Test Coordination contractor (SITC), and other
  contractors and users.

- Comprehensive reports and briefings informing the Air
  Force of the status and results of the contract.

Task 1 (Models Development) was accomplished to augment the
capability of the present DAIS facility. Models of a Maverick (AGM-65A)
television guided tactical missile and the VATS/Pave Tack laser designator
pod were developed and incorporated. This process followed a multi-step
procedure consisting of the following subtasks:

- Design, during which top-level and detailed flowcharts

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are made and revised as necessary;

● Coding and Checkout, during which the detailed
  flowcharts are transcribed into ANSI FORTRAN IV and the
  logic verified;

● Testing on a multi-step basis to ensure the model
  operates as required; and

● Maintenance as needed to ensure compliance with
  Configuration Control Board (CCB) directives.

The software methodology and standards followed for development of the models were detailed in the Software Management Plan. Figure 2 graphically depicts the process implemented during new model development.

During Task 2 (DMSS Enhancement) and concurrently with the development of the new models, the existing DMSS software was analyzed to determine the steps to be taken to optimize efficiency, enhance maintainability, and promote transferability.

A prioritized list of DMSS software components (executive, models, and utilities) to be enhanced, was established base upon:

(1) analysis of the current DMSS configuration and operation; and

(2) previous performance evaluations made by the SITC contractor.

Figure 3 depicts the enhancement process implemented during Task 2.

During Task 3 (Documentation Update), two principal objectives were accomplished:

(1) The existing DMSS Part II Specification and other
    associated documents were revised; and

(2) New documents were developed as required.
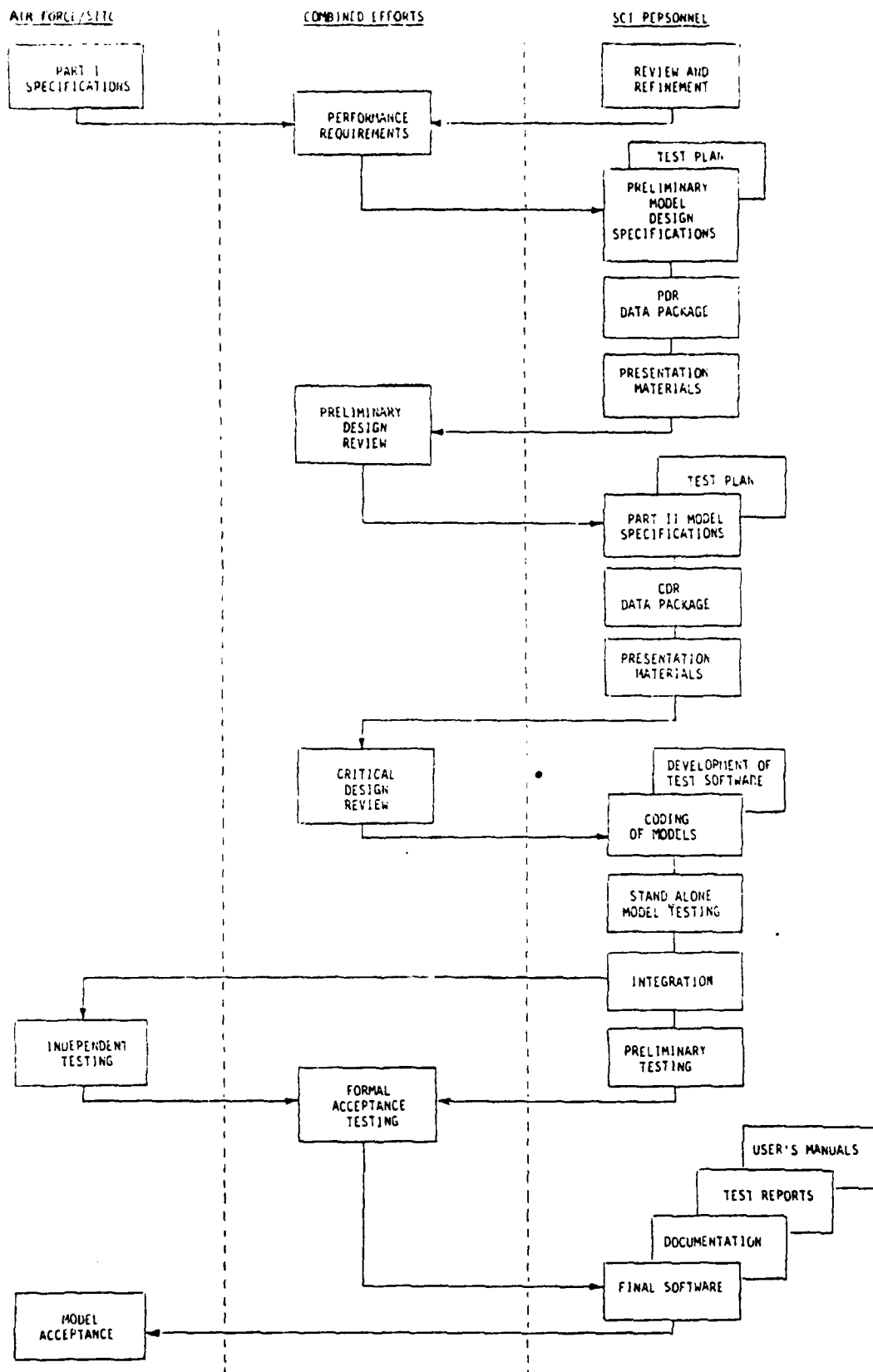
Figure 2
Procedure for Development
of New DMSS Models

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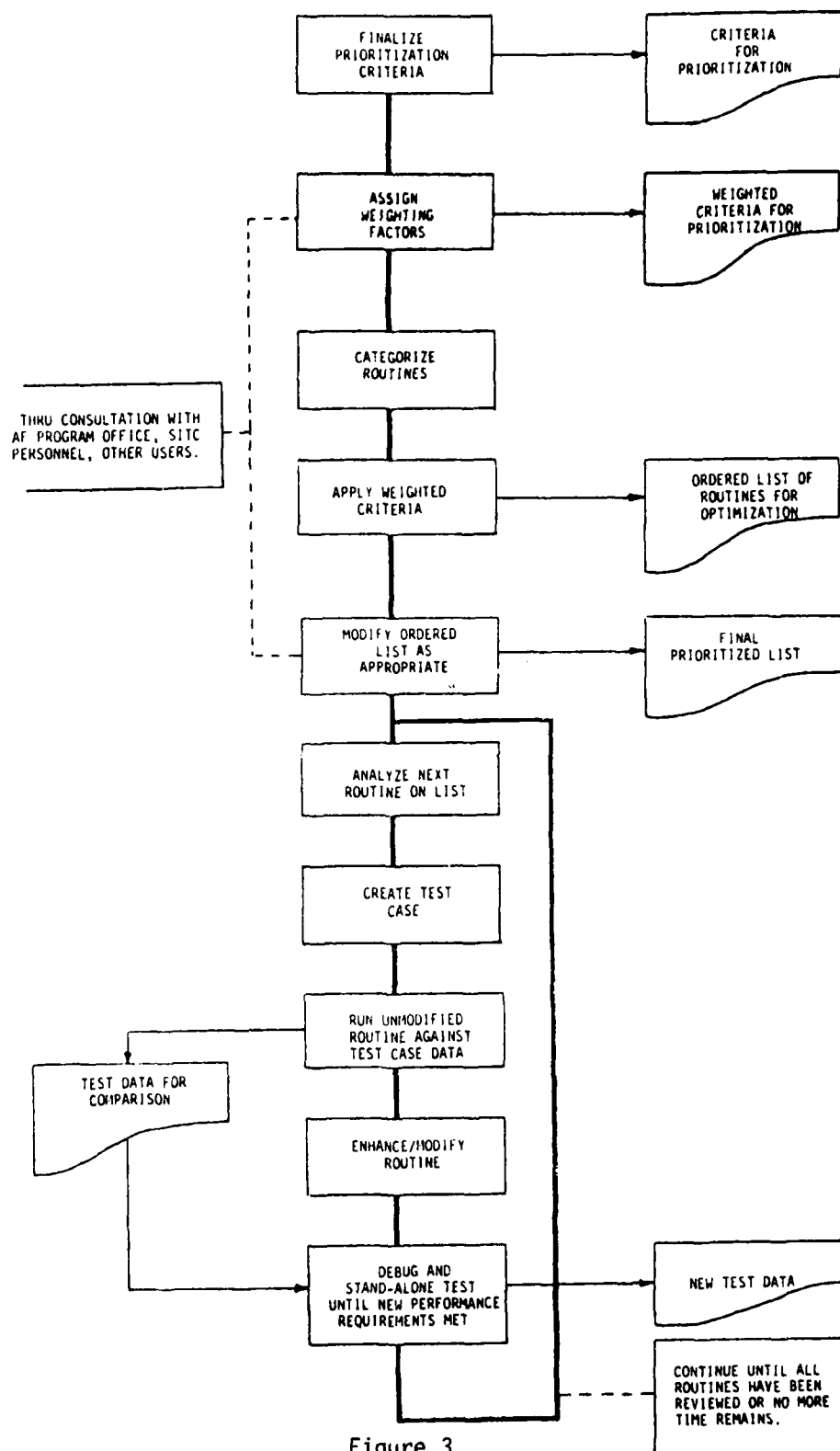
Figure 3
Models Enhancement Process

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All documentation was accomplished in accordance with MIL-STD-483 and MIL-STD-490. Documentation tasking was accomplished concurrently with new model development and enhancement tasking.

Task 4 (Software Management Plan) provided the Air Force with visibility into, and control over, the complete production and documentation of all software resulting from the DMSS Software Support Contract. The function accomplished by the Software Management Plan was to ensure that the technical objectives of the contract were met in a timely and cost-effective manner.

During Task 5 (Integration and Testing), software personnel were responsible for the integration of the Maverick and VATS/Pave Tack models into the system and the subsequent testing of the system. The integration and testing process ensured the compatibility of the models with their respective Interface Control Document descriptions. The integration and testing activities ensured that the new models and the enhanced executive and models performed their respective functions in a precise and timely manner.

A Computer Program Test Plan was prepared for each new model and the total DMSS in draft form. Test Reports for each new model and the total DMSS were delivered. These reports primarily addressed the test results (expected vs. actual) and recommendations for future action based upon these test results.

Task 6 (Engineering Services) involved software engineering support being provided to the Models Development Task as required. This support involved management, technical, and engineering support and services.

Task 7 (Liaison and Coordination) was included to promote

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understanding and coordination on an informal day-to-day basis. It
accomplished the following:

- A close working relationship with the AF Program
  Manager; and

- Soliciting of inputs, opinions, and feedback throughout
  all phases of the effort. Cross feedback between
  contractors on documents, plans, etc.

Task 8 (Training) ensured the continuation of an organic capability
within the Air Force with regard to DMSS operation and maintenance, and also
served to familiarize outside organizations with DMSS capabilities at both
the system and module levels. SCI provided comprehensive training using a
combination of detailed training materials, lectures, and meaningful
laboratory exercises.

Task 9 (Program Management) ensured the continuity and visibility
required by an effort of the size and complexity of the DMSS Software
Support contract. Specific areas encompassed by this effort included:

- Technical Reporting;

- Schedule Reporting;

- Physical Configuration Audits; and

- Adherence to Standards.

Detailed descriptions of the efforts conducted under each of the
tasks described are presented in the following paragraphs.

TASK 1 - MODELS DEVELOPMENT

The development of the documentation and software for the DMSS was accomplished in accordance with the Software Management Plan developed during Task 4. While the development of the Plan was accomplished in Task 4, in actuality it was one of the initial efforts completed by SCI in order to have it available prior to the software development effort. The following subparagraphs detail the various steps implemented during the models development task.

Design

During this subtask, personnel analyzed the existing development specification (SA 211 203, Part I) for the Maverick and VATS/Pave Tack simulation. The required interfaces with other DMSS software were investigated and the details concerning the two new models were verified with DAIS and SITC personnel.

Throughout the requirements analysis, pertinent data was summarized in a software development notebook. An initial design for each model, in the form of algorithms and flowcharts, was generated and subjected to detailed review by other members of the project team. A Preliminary Design Review (PDR) was conducted to ensure that the basic design approach met Air Force specifications. The overall risks associated with each model were reviewed on a technical, cost, and schedule basis. Fifteen days prior to the PDR, the Air Force Program Manager was furnished with the design review package for review.

The draft Part II Specification for each model was developed for presentation to the Air Force thirty days prior to the Critical Design Review (CDR). At the CDR, the draft Part II Specification and other design

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data for each model were analyzed to ensure that the proposed design solution satisfied the performance requirements established by the development specification. The review process ensured that any design modification established at the PDR had been incorporated. The interfaces between the new models and other DMSS software were reviewed for compatibility.

As a result of the CDR, the draft Part II Specification was revised and a draft version was issued. The final Part II Specification was delivered at the Preliminary Configuration Audit (PCA). The following sections describe the design approach for the Maverick and VATS/Pave Tack Models. The guidelines presented in the Software Management Plan were followed throughout their design.

Maverick Simulation

At the outset of designing the Maverick simulation software a requirements analysis was conducted. The analysis detailed the high risk and critical design requirements, along with the interfaces required between the software and hardware. A top-down design methodology was followed to provide traceability and facilitate software verification.

Inputs from DAIS Mission Software utilized in the Maverick simulation included:

- Elevation steering command;
- Azimuth steering command;
- Gyro spin-up power reset message;
- Master reset message;
- PAL/SAFE/MONF message;
- Option select message;

- Arm 1 sequence;

- Arm 2 sequence;

- Video/Power/Rack control message; and

- Release message.

Three sets of variables were used with the Maverick simulation: (1) input variables which provide information from mission software and other simulation routines; (2) internal variables which are necessary with the Maverick routines to simulate missile operation; and (3) output variables which are used by mission software and other routines.

Some of the variables utilized within the Maverick model to simulate the operation of the missile included:

- Missile field-of-view;

- Missile gimbal limits;

- Missile slew rate;

- Missile signal-to-noise ratio for lock-on and launch; and

- Gyro spin-up time.

The simulation outputs a monitor message to the mission software which describes the appropriate action to be taken. The functional interfaces between these variables and other software were detailed in the software development notebook. This notebook was used as a guide for coding, checkout, documentation, testing, and maintenance. Figure 4 depicts the top-level Maverick design proposed and approved during this effort.

The simulation of the Maverick can display to the pilot a set of crosshairs, representing the center line of the AGM-65A five degree field-of-view, and a target image on a graphics display. The elevation and
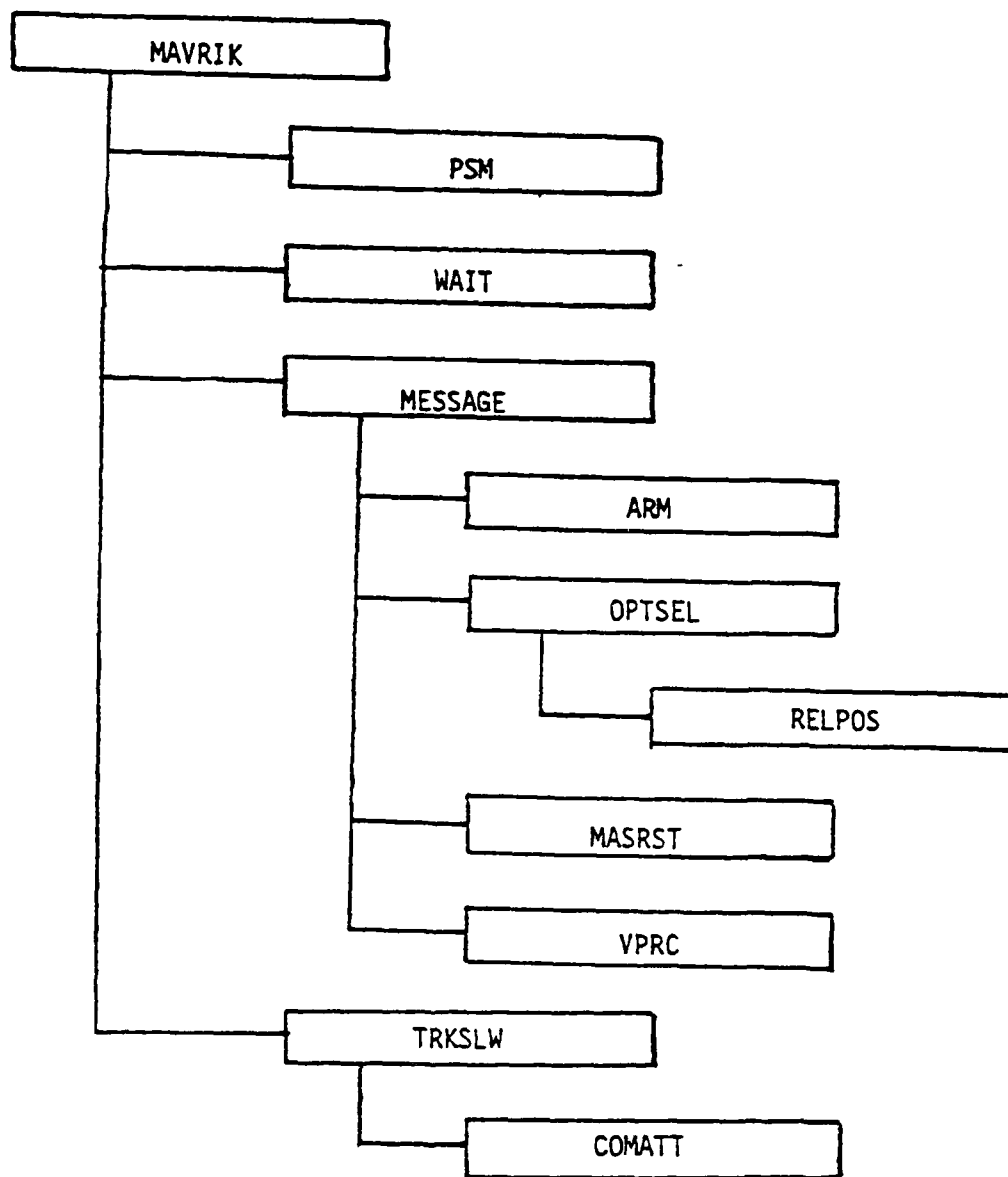
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Figure 4
Maverick Model
Top Level Flowchart

azimuth steering commands generated by mission software slews the missile camera's line-of-sight (LOS). The gimbal limits of the Maverick are checked to ascertain if they have been reached or exceeded, and the position of the target within the missile's field-of-view were calculated based on the aircraft's position relative to the target on a flat earth surface. The target image is driven based on these calculations. Once the target is centered in the crosshairs and designated, the simulation keeps the target centered unless the aircraft causes the simulated AGM-65A head to reach the gimbal limits. Detailed flowcharts of this operation were developed and updated as required during performance of subsequent phases of model development.

VATS/Pave Tack Simulation

The VATS/Pave Tack simulation is one part of the Sensor Simulation that models on-board aircraft sensors. At the outset of designing the VATS/Pave Tack simulation software, a requirements analysis was conducted. The analysis detailed the high risk and critical design requirements, along with the interfaces required between the software and hardware. A top-down methodology was followed to provide traceability and facilitate software verification. Figure 5 graphically portrays the VATS/Pave Tack top-level design utilized in developing this model.

Three sets of variables were used with the VATS/Pave Tack simulation: (1) input variables which provide information from mission software and other simulation routines; (2) internal variables which are necessary within VATS/Pave Tack routines to simulate pod operation; and (3) output variables which are used by mission software and other routines.

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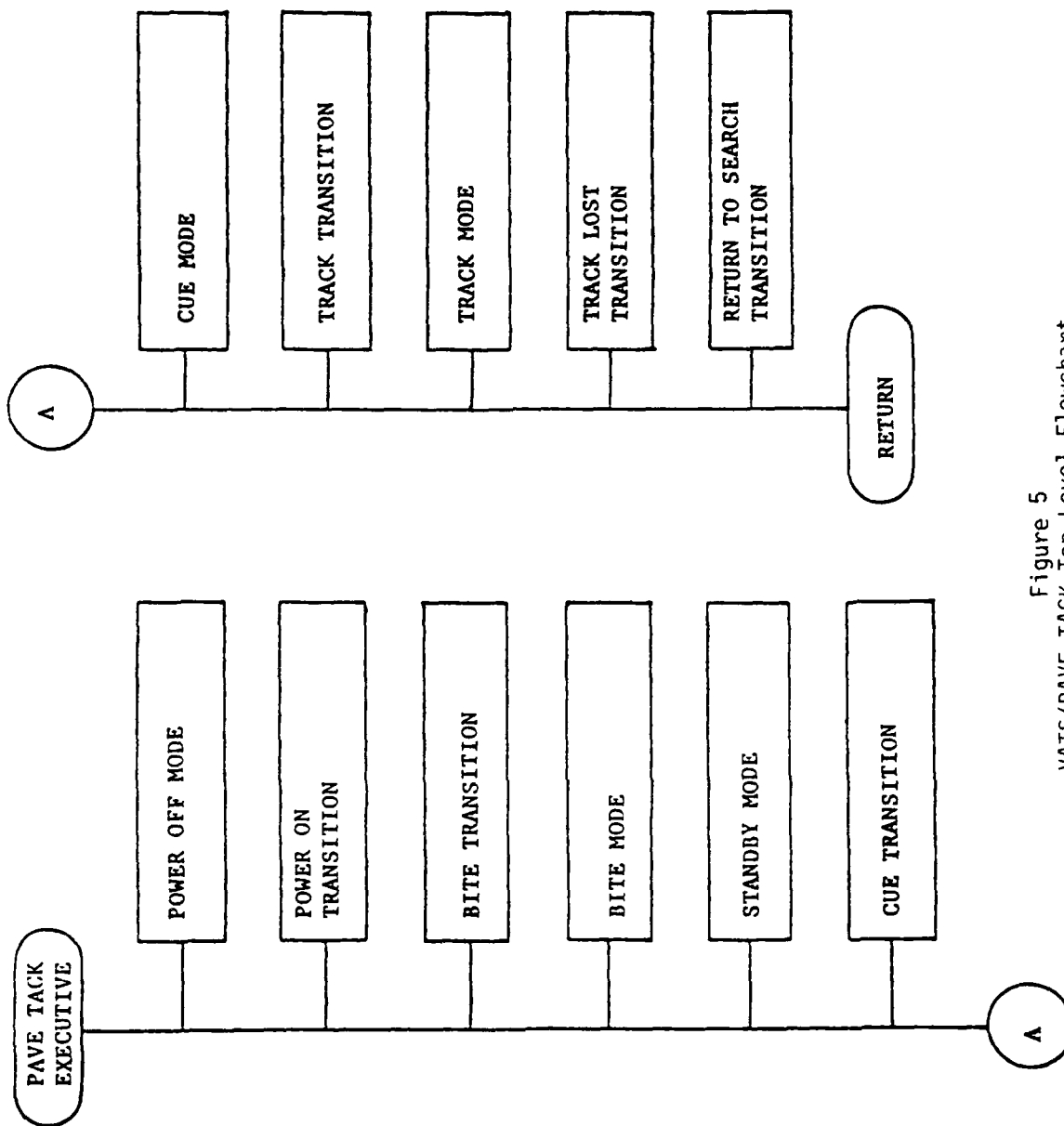
Figure 5
VATS/PAVE TACK Top Level Flowchart

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Some of the inputs from other DMSS software and DAIS Mission Software utilized in the VATS/Pave Tack simulation included:

- Mode Command - Off, Bite, Standby, Cue, or Track;

- Direction Cue - the cue is sent in the form of the
  north, east, and vertical components of the range to the
  reference LOS;

- Aircraft Velocity - north, east, and vertical components
  of ground speed; and

- Aircraft Attitude - yaw, pitch, and roll angles.

Some of the variables used within the VATS/Pave Tack Model to simulate the operation of the pod included gimbal angles and field-of-view. The outputs from the model to mission software included:

- Mode Status - indication of the current mode;

- Bite Response - go or no-go discrete;

- Track Discrete - discrete indicating the system is
  tracking;

- LOS direction cosines relative to aircraft body; and

- Slant range.

The functional interfaces between these variables and other software were detailed in the software development notebook. This notebook was used as a guide for coding, checkout, documentation, testing, and maintenance.

Coding and Checkout

Upon completion of the respective CDR, the coding of the Maverick and VATS/Pave Tack models was initiated. The flowchart and algorithms in the software development notebook and preliminary Part II Specifications were the bases for developing the actual code. The coding followed a

structured program logic flow to facilitate testing, maintenance, and documentation. By using top-down design techniques, portions of the models were checked out independently for correctness. The coding was accomplished in RATFOR (Rational FORTRAN) on the AFWAL AVSAIL DECsystem-10. Meaningful comments were inserted during the coding process to facilitate future software maintenance.

Before beginning formalized testing, all logic of the individual routines within the models was checked out, as was the entire model in a stand-alone configuration. This was accomplished by developing test drivers and checking out the individual routines prior to integration. Desk top checkouts were also conducted by software personnel to isolate more obvious deficiencies prior to actual model/system tests.

Testing

During the design of the models, a test plan for each model was developed. The test plan was delivered to the Air Force Program Manager prior to the PDR. This ensured that the programs would support the various levels of testing required. The testing was performed on two levels for each model:

- Stand-alone mode and

- Interface and functional testing

Test results were reported to the Air Force Program Manager. The draft Part II Specifications and User's Manuals were completed and formal delivery of the models and their supporting documentation made to the System Integration Branch. After acceptance by the Air Force Program Manager and SITC contractor, the product baseline models were placed under formal configuration control.

TASK 2 - DMSS ENHANCEMENT Due to the size of the DMSS software system, the routines were analyzed on a priority basis to ensure that available time and funds were effectively used to upgrade the existing software. The routines were ordered in a prioritized list, highlighting those routines whose optimization would most significantly improve DMSS performance. The first step in this task, involved finalizing the prioritization criteria which included the following:

- Memory utilization (larger programs were given high priority);

- Iteration rate (higher iteration rates were given greater priority);

- Frame loading (heavy frame loading were given higher priority); and

- Total routine execution time as a percentage of simulation run time (higher percentages were given higher priority).

All routines were processed against this criteria with the interim results indicated in Table 1. After Air Force review, an ordered list was developed (Table 2). Finally, a Final Prioritized List, grouping models interrelated or similar in nature, was developed and is depicted in Table 3. Enhancements were then initiated as indicated in the following paragraphs.

Efficiency

The efficiency of DMSS routines (executive, models, and utilities) was improved by decreasing core useage and/or execution time. The following improvements were included as applicable:

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Table 1

Interim Prioritized List

Prioritization Matrix of Routines to be Enhanced

Source Filename	Memory Size	Iteration Rate (group)	Program Length	Currently Documented	TOTAL
Weighing Factors	10	5	5	no=10 yes=0	
ADC1	1 / 10	6 / 30	1 / 5		45
AERO	1 / 10	6 / 10	1 / 5		25
AIRPLN	6 / 60	6 / 30	6 / 30		120
ATM2	3 / 30	1 / 5	2 / 10		45
A7BLOK	0	(data block)	1 / 5		5
BKCR3D	2 / 20	6 / 30	2 / 10	10	70
CALLER	2 / 20	6 / 30	1 / 5	10	65
CALP	6 / 60	7 / 35	3 / 15		110
CDRAC	1 / 10	6 / 30	1 / 5		45
CNTRL8	1 / 10	5 / 25	1 / 5	10	50
COCKPT	1 / 10	2 / 10	1 / 5		25
DCT	0	7 / 35	0	10	45
DIR	6 / 60	7 / 35	3 / 15		110
EARTH	4 / 40	6 / 30	2 / 10		80
EXECIN	1 / 10	1 / 5	1 / 5		20
EXEC2	1 / 10	7 / 35	1 / 5		50
FCNAV	4 / 40	6 / 30	3 / 15		85
GUDES	3 / 30	6 / 30	1 / 10	10	80
ICIM	0	6 / 30	0		30
ILS1	4 / 40	3 / 15	3 / 15		70
INSTRM	1 / 10	5 / 25	1 / 5	10	50
INU	6 / 60	6 / 30	5 / 25		115
LAND	4 / 40	6 / 30	3 / 15	10	95
LSR	2 / 20	6 / 30	1 / 5		55
MKB25	2 / 20	6 / 30	2 / 10	10	70
PAVPEN	?	?	2 / 10	10	10
PROPEL	1 / 10	6 / 30	1 / 5		45
RADALT	2 / 20	3 / 15	2 / 10		45
SCEN	3 / 30	7 / 35	2 / 10		75
SCORE9	4 / 40	6 / 30	1 / 5	10	85
SUPER	1 / 10	7 / 35	1 / 5		50
TACAN	6 / 60	3 / 15	2 / 10		85
TRAJEC	6 / 60	6 / 30	5 / 25		115
TRANS	1 / 10	6 / 30	1 / 5	10	55
WIND	1 / 10	?	2 / 10	10	30

to nearest 100 words	cont = 7	page length of uncompiled sources
0-5 = 1	64 = 6	1-5 = 1
6-10 = 2	32 = 5	6-10 = 2
11-15 = 3	16 = 4	11-15 = 3
16-25 = 4	8 = 3	16-20 = 4
26-40 = 5	4 = 2	21-25 = 5
OVER 40 = 6	2 = 1	OVER 25 = 6

TABLE 2

ORDERED LIST FROM THE MATRIX ARRANGED
BY TOTAL SCORE

AIRPLN

TRAJEC   INU

CALP [1]   DIR [1]

LAND

FCNAV   SCORE9   TACAN

EARTH   HUDES

SCEN [1]

BKGR3D   ILSI   MK82S

CALLER

LSR   TRANS

CNTRLS   EXEC2[1] INSTRM   SUPER[1]

ADC1   ATM2   CFDRAG   DCI [1]   PROPEL   RADALT

WIND   ILIM

AERO   COCKPT

EXECIN [1]

PAVPEN

A7BLOK   Common

1-These are all executive routines

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TABLE 3

FINAL PRIORITIZED LIST GROUPING THOSE MODELS
INTERRELATED/VERY SIMILAR

AIRPLN	LAND	AREO	PROPEL			
TRAJEC	CFDRAG					
INU	FCNAV					
CALP	DIR	SCEN	MAIN	EXEC2	DCI	EXECIN
SCORE9	HUDES	BKGR3D	CALLER			
TACAN						
EARTH						
CNTRLS	INSTRM	COCKPIT				
ILSI						
MK82S						
LSR						
TRANS						
ADC1						
ATM2						
RADALT						
WIND						
ILIM						
PAVPEN						
A7BLOK						

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- Delete unused subroutines, variables, and lines of code.

- Use integers amd smaller arrays wherever feasible.

- Locate the innermost loops and decrease their size.
  (This section of code is executed the most often so
  cutting size will decrease both execution time and core
  useage.)

- Make operands all the same type in arithmetic statements
  if possible. (This will decrease conversions needed
  between data types.)

- Define data to end on word or byte boundaries.

- Place the most likely true first in conditional
  statements. (For example, in a complex .OR., put the
  truest first. This saves multiple compares.)

- Minimize branching on conditions as much as possible.
  (Jump only on least possible condition so as to execute
  the shortest path.)

- Check out table searching techniques. (For example, is
  it necessary to search the table or can an existing
  subscript be used as an index?)

- Check individual routine priority and scheduling rates
  and consider reducing if quality of simulation is
  unaffected.

- Isolate overly precise calculations and relax model
  accuracy if simulation performance is not degraded.

In addition to the individual model enhancements, the restructing of
the load module was analyzed so that only essential routines will be

core-resident during real-time execution. Appropriate modifications were then incorporated.

Portability

Future mission requirements were reviewed with the Air Force Program Manager and it was determined which computer systems were being contemplated as potential DMSS hosts. Principal candidates located and considered during this effort were the PDP-11 and VAX-11/780. In those cases where these specific computer systems were identified as a highly likely host machine, the feasibility of transferring the models systems was assessed. The results of this analysis were utilizied to re-order the prioritization status of the DMSS routines. The following enhancements were employed, as required:

- Meaningful explanatory comments were inserted to facilitate future modifications and maintenance.
- Esoteric, obscure coding was restructured for maintainability if efficiency was not impaired, or was annotated with detailed commentary.
- Hardware dependent interfacing was isolated and reorganized into a small set of subroutines.
- Top-down, modularized restructuring was accomplished where possible.

Coding and Checkout

This subtask involved modifications to the routines to meet the objectives outlined in the priorization lists. Changing the source code (both FORTRAN and DECsystem-10 assembler) and creating new code (as required) was accomplished by the project team. Subsequent program test was

then completed for all modified software. A change log file was created in which every change was documented. This aided in the final documentation of the modules and prevented repetition of errors. All changes made to the existing software adhered to the techniques/standards established in the Software Management Plan.

The following three different libraries of the DMSS software were maintained:

(1) Released (a copy which has met the ATP);

(2) Working (an intermediate version for the testing of
changes in other modules); and

(3) Individual (one per programmer - this is the version
undergoing day-to-day changes).

The modified code was tested via previously developed test procedures at the system level with the simulated interface acting as the mission software and associated hardware.

Testing

To allow errors to be more readily isolated, each routine was tested individually as it was modified, when possible. The testing ranged from stand-alone to simulated interface/functions testing. This approach minimized the total time needed in the final testing phase. A test case was created for each routine and a baseline test was run prior to changing the code. A standard then existed against which to check results. This procedure ensured that only fully operable software routines were delivered to the System Integration Branch for "re-acceptance" and system integration testing.

Formal acceptance testing was accomplished in accordance with test

procedures written during Task 5. The DMSS software was then tested at the system level with the mission software.

Maintenance

DMSS software problems were documented by Air Force personnel, submitted for consideration, and corrected as approved by the CCB. The appropriate documentation was also modified as these changes were made. Testing of modifications was accomplished according to the approved test procedures. Modifications were made following the programming standards established in the Software Management Plan.

TASK 3 - DOCUMENTATION

The proposed documentation approach was an integral part of both the development and enhancement tasks, and resulted in the delivery of the updated Part II Specification and User's Manual.

Part II Specification

The Part II Specifications for the VATS/Pave Tack and Maverick models were developed for incorporation into the existing DMSS Part II Specification. MIL-STD-483 and MIL-STD-490 were utilized as the principal guidelines throughout the documentation effort. The final format and content definition was coordinated with appropriate Air Force and DAIS contractor personnel, and was subject to review and approval by the Air Force Program Manager. These tasks were accomplished as described in the following subparagraphs.

Development of New Models Specifications

Since approved programming and documentation practices were enforced, the development of Part II Specification inputs covering the new models was accomplished more efficiently than upgrading the existing DMSS

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documentation. A software development notebook was maintained for each new model detailing the functional capabilities, interfaces, design, and testing requirements as detailed in the Software Management Plan.

Particular emphasis was placed on the creation of program flowcharts. Flowcharts were developed with enough detail to directly reflect the coding they represent, but sufficiently functional to obviate changes for every code change. During coding and checkout, all flowcharts were updated as necessary to reflect corrections and modifications made during debugging. Finalized versions of these flowcharts were prepared to a level of detail commensurate with that used in the Part II Specification. During the coding process, the programmer inserted meaningful comments from the flowchart into the code.

Revisions of Present DMSS Part II Specification

The orginal Part II Specification (SA 211 203), dated 30 June 1977, was reviewed and revisions to this document were accomplished as follows:

(1) Revision of the format, organization, and content to conform to the guidelines for Part II Specifications established by MIL-STD-483 and MIL-STD-490 as approved by the Air Force Program Manager.

(2) Detailed review of each model/module/utility documentation to assure modifications in the Specification reflect all changes due to optimization, enhancement, and restructuring accomplished during Task 2.

(3) Development and incorporation of Part II Specifications for sensor models, utilities, etc., which were used in the current DMSS configuration but not previously

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documented.

(4) Incorporation of Part II Specifications for the new models developed during the effort (Maverick and VATS/Pave Tack).

Subtasks (1) through (4) were accomplished concurrently with the new models development and the enhancement tasks.

The existing Part II Specification was analyzed to ascertain if sufficient information was available to meet the content requirements of MIL-STD-483 and MIL-STD-490. Individual model/utility specifications found deficient in this respect were noted. Specification upgrading was initiated with those routines considered to be of lowest priority for enhancement. This was accomplished in order to minimize the schedule risk associated with the revision of such an extensive system.

Concurrently with documentation review, software personnel began analyzing and modifying DMSS modules assigned highest priority for enhancement. The enhancement of each routine was accomplished by assigning work packages to software personnel. The work package clearly defined the enhancement task to include the addition of meaningful source code comments; review and change (or preparation of) specification data; development of a test plan; and the actual restructuring and/or optimization of the routine's code. Each finished work package was reviewed for completeness by the Project Manager. The DMSS Part II Specification was formally submitted to the Air Force for final review and distribution.

User's Manual

The existing User's Manual(MA211203), dated 30 June 1977, was reviewed for conformance to DI-M-3410 as clarified and amplified by the guidelines published in PA000105 (DAIS Guidelines for Development of User's Manual), and the following five categories .f changes were recommended:

(1) Complete reorganization and revision of the User's
    Manual to more closely conform with DAIS manual format
    and content requirements, and to allow a
    non-software-oriented user to operate the simulation
    with minimal assistance.

(2) Inclusion of sections describing Maverick
    and VATS/Pave Tack model and currently used models not
    pre iously documented.

(3) Deletion of sections describing models no
    longer utilized in the current DMSS configuration.

(4) Deletion of informative but unnecessary sections
    from the main body of the manual.

(5) Inclusion of more user-oriented information
    in the form of specific examples of how to create and
    run typical simulations, starting with the most basic
    simulation (which would include the minimum number of
    models) and including an advanced simulation (which
    would include the number of models commonly used).

The updating of the User's Manual was accomplished in parallel with the updating of the Part II Specification. Individual model enhancement/optimization activities had little effect on the User's Manual.

Upon completion of the DMSS User's Manual update, it was formally submitted to the Air Force for final review and distribution.

TASK 4 - SOFTWARE MANAGEMENT PLAN

The Software Management Plan defined the methodology to be used in developing new DMSS software and in maintaining and enhancing existing DMSS software. It covered the following software development areas:

- Specification of performance requirements;
- Formulation of preliminary design specifications and top-level flowcharts;
- Formulation of test plans and test procedures;
- Presentation of designs for formal review;
- Coding and commenting practices and standards;
- Testing, formal and informal;
- Documentation of test results;
- Documentation of software and revision of User's Manual and Part II Specification;
- Internal configuration control procedures and compatability with external procedures; and
- Detailed contract schedule.

The objective of the Software Management Plan was to ensure the orderly and efficient development or modification of DMSS software. The long range goal of the plan was to ensure the low life cycle cost of the software, and to make it easily adaptable and transportable so as to effectively meet future simulation requirements of DAIS or similar programs.

The plan required full use of, and compatiblility with, existing software development guidelines already available within the Avionics

Laboratory. The plan focused on the procedures to be used internally to develop or enhance the software, since these methodologies are extremely important if efficient, timely delivery of software and documentation is to be realized.

The Software Management Plan was basically divided into two sections reflecting the twofold nature of the DMSS Software Support contract: (1) development of new software, and (2) enhancement of existing software. There was a large measure of commonality between the management requirements for these two basic tasks, yet sufficient differences existed to warrant separate discussions.

TASK 5 - INTEGRATION AND TESTING

The goal of the integration and testing activities was to ensure that the new models and the optimized executive and models perform their respective functions in a precise and timely manner. Following the design and coding of the Maverick and VATS/Pave Tack models, software personnel were responsible for the integration of these models into the system and subsequent system testing. The integration and testing process ensured the compatibility of the models with their respective Interface Control Document descriptions.

A draft Computer Program Test Plan was prepared for each new model and the entire DMSS and delivered to the Air Force Program Manager. These documents defined the test requirements necessary to verify that the DMSS software met the approved performance requirements. Test Reports for each new model and the total DMSS were developed based upon test results delivered to the Air Force. These reports primarily addressed the test results (expected vs. actual) and recommendations for future action based

upon test results. The types of testing performed are discussed in the following subparagraphs.

Stand-Alone Testing

Module specifications were analyzed and test cases identified that would exercise the module not only at the extremes but across its dynamic range. To support this method of testing, a "test driver" designed to exercise the module with preselected test cases was developed.

Using this tool, the various module inputs were specified, and the outputs of the module monitored as a function of time. The test cases were accessed on a test case to test case basis. Each test case contained the input values.

Interface and Functional Testing (IFT)

Each enhanced model was individually tested in the total simulation system by being linked into a baselined scenario-driven system allowing repeatability of the flight scenario. The outputs of the module were compared to a file of baseline outputs by printing out the test run data and the compatible baseline data for visual comparison by the IFT test team.

Acceptance Test Procedure (ATP)

After all the models successfully passed IFT, the DMSS was rebuilt with all the enhanced models included. This testing was the responsibility of the System Integration and Test Coordination (SITC) contractor with SCI providing assistance as needed. The ATP consisted of running the enhanced DMSS through the standard DAIS system test and paying particular notice to the options/selections that are DMSS dependent. The ITB had to be fully operational for this testing. After the enhanced DMSS passed ATP it was accepted for distribution.

TASK 6 - ENGINEERING SUPPORT SERVICES

Throughout the term of the effort, engineering support services were provided on an as required basis in the following areas:

- Development and documentation of a Global Cross
  Reference System (SETUSE);

- INU model enhancement consultation;

- SORT Program User's Manual development;

- Enhancement task consulting;

- New Models Development Task consulting; and

- Airplane model enhancement consulting.

TASK 7 - LIAISON AND COORDINATION

In a program of the size, complexity and scope of the DMSS Software Support Effort, liaison and coordination with the Air Force user, technical and management is vital to overall project success. Some of the specific persons and organizations with whom interfacing was required included:

- The SITC contractor and the DAIS Program Branch to
  ensure that the design of the new models adhere to
  overall DAIS goals.

- The Configuration Control Board (CCB) and users to main-
  tain the software and enhancements.

- AVSAIL personnel for development of COMMON block
  standards, etc.

- Cognizant individuals, who have impacts on the
  Preliminary Design Reviews (PDR) and Critical
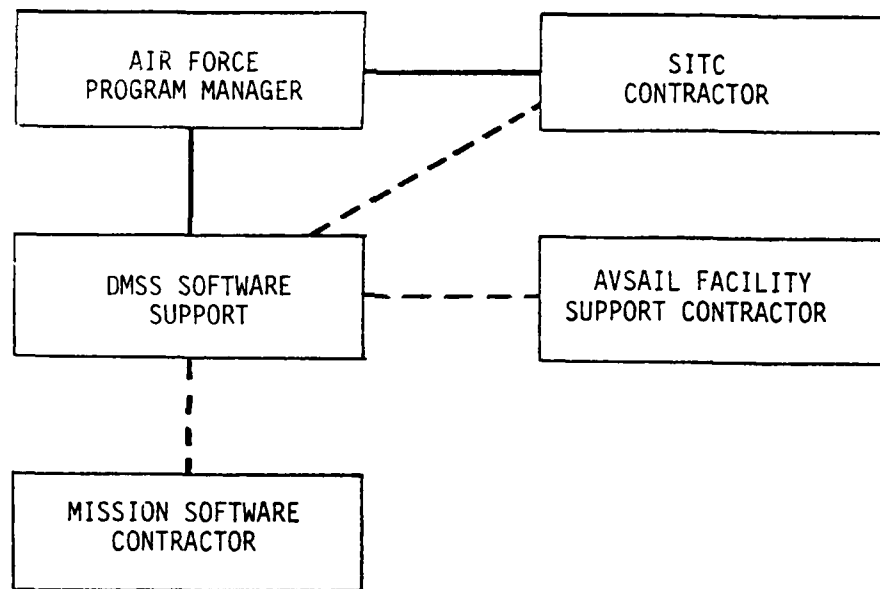 Design Reviews (CDR), for critiques and inputs.

Figure 6
Liaison and Coordination

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The SCI Project Manager was responsible for ensuring that all activities were coordinated. On a formal basis, status meetings were held to be certain that all ideas and opinions were available to the various groups. The format, scheduling and agendas were coordinated with the Air Force Program Manager. Figure 6 depicts the liaison and coordination which was required during this effort.

TASK 8 - TRAINING

The training task was considered to be an important element of the DMSS Software Support Contract since all personnel associated with the system should possess the necessary knowledge and skills to use it effectively. Features of the training task included:

- Coordination with the AF Program Manager and other
  cognizant Air Force and contractor personnel to identify
  training requirements (i.e., level of detail, number of
  class participants, scheduling, etc.).

- Development of detailed lectures, examples and
  presentation materials designed to fully acquaint the
  students with the subject matter. Presentations,
  classroom lectures and examples were submitted to the
  Air Force Program Manager for review. Classroom
  materials were distributed on the first day of class for
  each course.

The Maverick Missile and VATS/Pave Tack course and the DMSS Optimization/Enhancement course are detailed as follows.

Maverick Missile and VATS/Pave Tack Course

The Maverick Missile and VATS/Pave Tack course were scheduled after

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the integration and testing of these new models into the DMSS. The training topics and materials included:

- Detailed description of each model, its major objectives and underlying (simplifying) assumptions.
- Review of the design specifications.
- Development tradeoffs, size and timing constraints considered during the design stage.
- Detailed flowchart, input, output and interface descriptions and narrative descriptions as presented in the Part II Specification and User's Manual.
- Detailed description of model operation including organization and definition of variables and other data structures.

Operation of DMSS

The operation of the enhanced D   training course was scheduled after the executive optimization and models enhancement tasking was completed. The training topics included:

- DMSS Overview
- Executive Software
- Sensor Models
- SLU/Stores Models
- Environment/Aircraft Models
- Utility Software
- DMSS Interfaces
  - DAIS Mission Software
  - Controls and Backup Instrument System

- DECsystem-10 DMA-10 Window

Training materials included the analysis of executive software and models chosen for enhancement and the User's Manual.

TASK 9 - PROGRAM MANAGEMENT

Program management was responsible for technical and financial guideline of the project throughout its life cycle. Personnel assignments and reporting procedures were also a principal consideration of the effort. A Contract Work Breakdown Structure (CWBS) was prepared, and updated during contract performance to reflect changes in the scope of effort, requirements definition, or alternative approaches. All updates were coordinated with the DAIS Program Office and subject to approval of the DMSS Program Manager, the Air Force Program Manager, and the DAIS Procuring Contract Office (PCO). The following subparagraphs detail program management reporting against the CWBS.

Technical Reporting

Status and progress reports summarizing work accomplished, activity planned for the month, and description of problems encountered and subsequent remedial action were prepared and delivered to the Air Force on a monthly basis.

Schedule Reporting

Monthly program schedule and financial reports in accordance with Contract Data Requirements List (CDRL) seqs. 7, 20, 21, and 22 were prepared and delivered. The Program Schedule portrayed major DMSS milestones and indicated progress made between reporting dates. Person hours and Funds Expenditures Charts plus a Performance and Cost Report were provided to enable both graphical and numerical comparisons/analysis.

Physical Configuration Audit

Upon completion of the DMSS optimization (including integration of the new models and successful ITB testing), a Physical Configuration Audit was conducted in accordance with the requirements of the DAIS Configuration Management Plan. The audit included a detailed review of format, content, and completeness of the DMSS Part II Specification, User's Manual, and Test Reports.

SUMMARY

Successful completion of the DMSS Software Support contract was predicated principally on three factors:

(1) The detailed and phased approach outlined in this Section;

(2) The development of, and adherence to, a comprehensive Software Management Plan approved by the Air Force; and

(3) Constant liaison and coordination with the Air Force throughout the entire effort.

Based upon some modifications to the projected schedule and technical tasking flow, deviations from the proposed approach occurred during the effort. In order to highlight these deviations and the associated rationale, they have been made the subject of the next section of this report.

SECTION IV

DEVIATIONS/MODIFICATIONS

INTRODUCTION

The previous section described the technical approach for the DMSS Software Support effort. This section enumerates the deviations from, and modifications to, the original approach and the supporting rationale for these changes.

FORTRAN/RATFOR ANALYSIS

As the principal thrusts of the DMSS effort were the transportability and enhancement of the models, top-down structuring techniques were used. Top-down structuring improves maintainability because it is readily understood by system maintenance personnel. However, FORTRAN-10 does not support structured constructs of IF-THEN-ELSE, WHILE, and REPEAT-UNTIL, thus the structured FORTRAN preprocessor RATFOR was investigated for possible use. RATFOR converts structured FORTRAN-like programs into ANSI FORTRAN for compilation.

One of the enhancement models RADALT, Radar Altimeter, was optimized in FORTRAN-10 and RATFOR. The memory utilization for the RATFOR version was 435 words while the FORTRAN version was 428 words (an increase of less than 2%). The readability and understandability of the RATFOR version was very favorable. The RATFOR preprocessor was written in FORTRAN IV (so it could be transported to another computer) and the Digital Equipment Computer User Society (DECUS) also can supply a version of RATFOR. The decision was then made to restructure all model routines into RATFOR. This decision had no schedule or level-of effort impact on the DMSS Software Support Project.

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GLOBAL CROSS REFERENCE

Because the global variable usage was an intricate part of DMSS and it was difficult to track down the routines using different global variables, a global cross reference analyzer was developed as part of the engineering support task. This program listed out all global variables used by the subject subroutines and then specifies if the variable was set, used, or passed as a parameter.

COMMON BLOCK STANDARDS

As part of the liaison task, an SCI representative attended meetings of the AVSAIL COMMON Block Standards Committee. The results of these meetings were documented in IE 004 1000 (COMMON Block Standards for AVSAIL Avionics Models). After receiving Air Force concurrence to increase the scope of the DMSS Software Support effort, the enhancement task renamed all variables used to reflect the COMMON Block Variable Names standards. These standards required a reorganization of the variables within the COMMON Blocks which was accomplished as part of this effort.

ENHANCEMENT FOR ASD

In June, 1980 for the transition of DAIS technology to the Integrated Digital Avionics (IDA) program, the scope of the enhancement task was increased to include the rehosting of some of the DMSS software to System Engineering Analysis Facility (SEAFAC) at ASD. This rehosting consisted of transferring the Run-Time Monitoring Program (MONI) to a PDP-11/55, transferring the Post Run Analysis routines onto a VAX-11/780, transferring the Checkpoint/Reset routines onto a VAX-11/780, and creating a guideline for development of Interface Control Documents.

The MONI program displayed in real-time specified bus messages and simulation variables. The Post Run Analysis software tabulated and plotted

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data that was logged during the real-time simulation. This routine can be executed anytime after the simulation has been completed. The Checkpoint/Reset routines allows a simulation user to take a checkpoint of data anytime during the simulation, while the reset portion will reinitialize the simulation to any specified checkpoint. The Interface Control Document specifies variables and bus message formats for that data which is transferred from one hardware system to another in the real-time simulation.

The following documents were delivered to SEAFAC:

- Run-Time Monitoring Program (MONI) Part II Specification;
- MONI User's Guide;
- Post-Run Analysis Part II Specification;
- Post-Run Analysis User's Guide;
- Checkpoint/Reset Part II Specification;
- Checkpoint/Reset User's Guide; and
- Interface Control Documents (ICD) Guidelines.

The test plans for each of the software products were included in section 4.0 of the respective Part II Specification.

INTEGRATED TEST BED

Some enhanced models were ready for testing in April. However, in spending 10 hours on attempting Integration and Functional Testing (IFT) on the DAIS Integrated Test Bed (ITB) and only accomplishing 2 hours of actual testing, it was decided to change the planned testing approach. SCI would still conduct the Stand Alone Testing and Preliminary Qualification Tests (PQT) with the Air Force Program Manager and SITC reviewing the results. With unreliable hardware in the ITB, it was more efficient for the Air Force

and SITC to conduct the IFT with SCI personnel being called upon only for complex problems. Working in this mode for several months, about one half of the models were tested. Finally the hardware system was sufficiently reliable to allow SCI and Air Force personnel to spend 20 hours in one week during November for IFTs on the last half of the enhanced models.

The ITB unreliability was due to inconsistencies of the following hardware:

1) Cockpit Controls and Displays

  • Not initializing correctly; and

  • Locking-up in the middle of testing.

2) DECsystem-10

  • Having some memory off-line;

  • Allocating DMA channels; and

  • Slave processor has instruction problem (DMSS must run on the slave).

3) On-board Processors

  • Problems with BCIU;

  • Booting the processors; and

  • Problems with power supply.

Occasionally, the other hardware which interfaces with the ITB had minor operating difficulties. They were the Evans & Sutherland Picture System and the Simulated Subsystem Data Formatter (SSDF). Unfortunately, the hardware unreliability impacted the ATP to the point where the ATP has not to date been performed. All of the enhanced models have individually been tested on the full ITB and some loads of various enhanced models combinations have been tested.

These hardware problems also impacted the enhanced DMSS training. Actual exercises on the DMSS execution could not be presented for the student's benefit.

SYSTEM HARDWARE

SCI personnel also found some difficulties in using the DECsystem-10 for the models enhancement. This was primarily due to terminal response time during normal working hours. The SCI in-house PDP-11/34 was used for development and testing of all of the enhanced models. Only portions of code handling the bit manipulations could not be fully tested on the PDP-11. This approach to computer usage increased the productivity of the enhancement and new models development staff as it cut down the travel time needed for picking up listings or for using a high speed terminal, and it eliminated unproductive time from DECsystem-10 periods of unreliability and down-time. The PDP-11/34 was used as a word processor for the production of the Part II Specification and other DMSS documentation. This usage reduced the amount of re-typing and proofing.

FLOW DIAGRAM GENERATOR

Also in support of the Part II Specification production, an automatic flow diagram program was utilized by SCI on the PDP-11/34. This program took a RATFOR source code routine and created a structured flowchart which was produced on a Printronix dot-matrix printer. The total amount of PDP-11/34 computer time used in support of the DMSS effort for both model developent/enhancement and for word processing is depicted in Figure 7.

	Hours	CPU Units
Jun 79	4.5	400
Jul 79	9.3	480
Aug 79	15.0	7,000
Sep 79	29.6	16,500
Oct 79	219.5	499,000
Nov 79	452.4	1,167,600
Dec 79	211.1	1,208,340
Jan 80	90.0	193,700
Feb 80	133.7	232,038
Mar 80	56.0	896,561
Apr 80	187.2	1,171,787
May 80	201.7	758,810
Jun 80	229.9	873,767
Jul 80	357.4	768,939
Aug 80	76.3	84,072
Sep 80	324.0	388,858
Oct 80	2,710.9	573,398
Nov 80*	1,000.0	240,000

* Estimated

Figure 7
SCI PDP-11/34 DMSS Usage

SECTION V

OBSERVATIONS AND RECOMMENDATIONS

PERSON HOURS

At the request of the Air Force and for use in future estimates, the following personhours expended for the new models development (from design through PQT) are presented. For the Maverick Model, 660 hours of Senior Systems Analyst time and 68 hours of typing/drafting support for the preparation of design review packages and documentation. For the VATS/PAVE TACK Mcdel it took 604 hours of Senior System Analyst time and 60 hours of typing/drafting supporting.

There were a total of 1320 hours of Senior System Analyst time and 1100 hours of Programmer time expended during the models enhancement task. This time did not include IFT time which was considered part of Task 5 (Testing). A total of 22 major models were enhanced under this effort.

REVIEW MEETING PREPARATION

SCI recommends that the time between delivery of design review packages and the actual review be decreased. The existing periods cause the new model developer to absorb approximately 2 to 4 weeks of relatively non-productive time when awaiting the review.

SOFTWARE DEVELOPMENT NOTEBOOKS

SCI maintained software development notebooks for each new and enhanced model. It is recommended that these notebooks should have stricter review by the SCI Program Manager for completeness and consistency.

DOCUMENTATION

The Part II Specification section for each individual model should have been finalized as soon as that model passed PQT. There were only minor changes made to the routines during IFT and the documentation should be

finalized while the model is still fresh in the enhancer's mind. Documentation schedules should be strictly adhered to during future efforts.

FINAL RESULTS

Improvements were made in the core useage and execution times of the DMSS. The load module decreased from 97K words to 68K words (a decrease of 27%). The size of COMMON was changed from 21K words to 15K words (29% decrease). The time required for loading and locking the load module into core decreased from an average of 64.5 seconds to about 42 seconds (36% improvement). These changes should favorably influence many possible users of the DMSS.

FUTURE CONSIDERATIONS

There are many utility, data logging, and real-time assignment routines within DMSS which are inefficient and poorly designed and coded. These would be greatly improved with code enhancement and conformation to naming standards.

It is also suggested that the DMSS be transported to one of the existing PDP-11s in the AVSAIL facility. If it is possible to effectively run the models on a PDP-11 the reliability problems of the DECsystem-10 could be ignored for ITB system testing.

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